X-ray Reflection Grating Update

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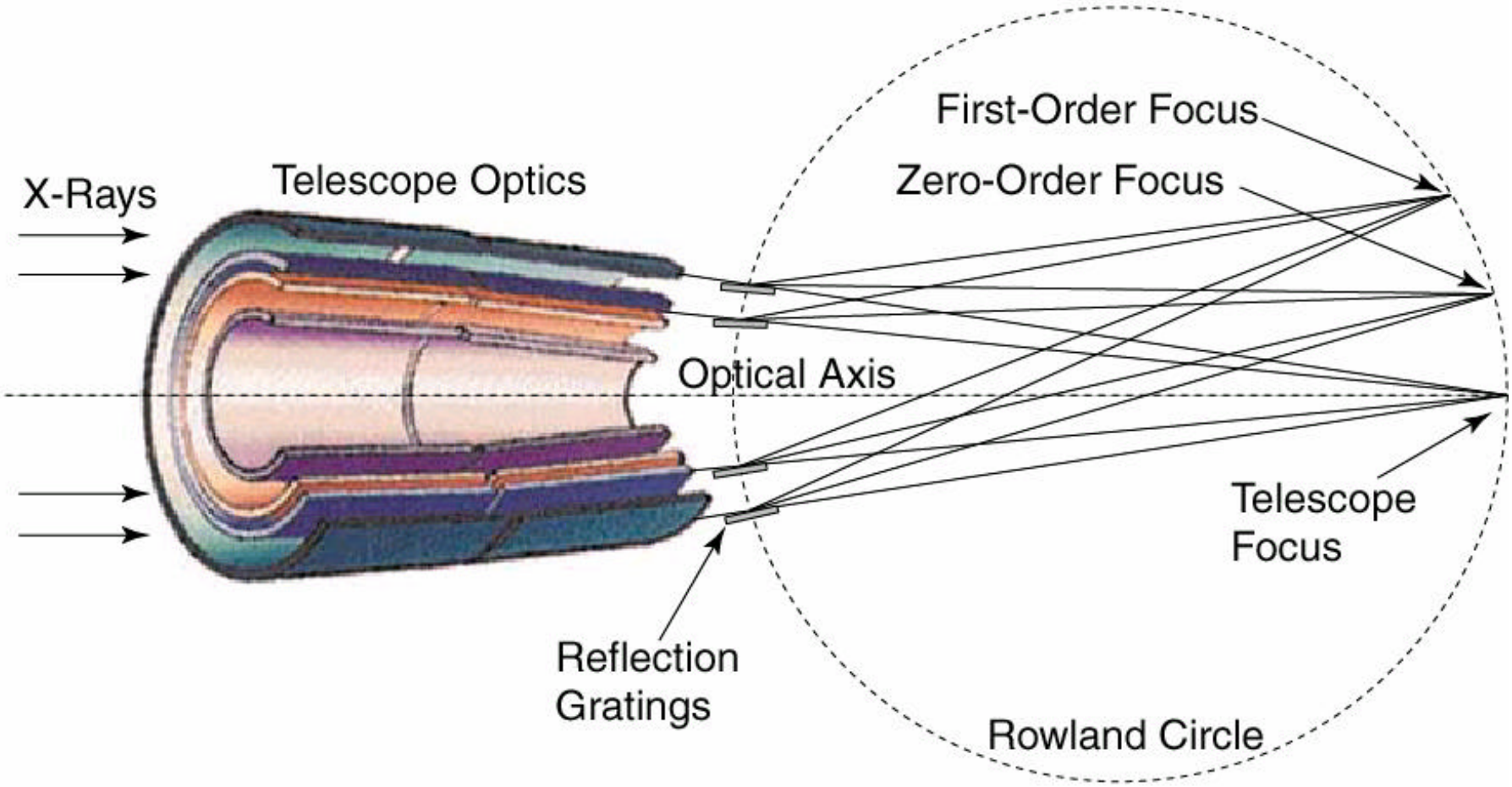
Outline

- Review of Wolter telescope reflection grating optics
- Grating design
- Flat substrate research
  - Thermal shaping
  - Block lapping
  - Magnetorheological finishing
- Assembly of flat substrates
  - Design overview
  - Flexure bearings
  - Micrometer array

Wolter Telescope Reflection Grating Optics



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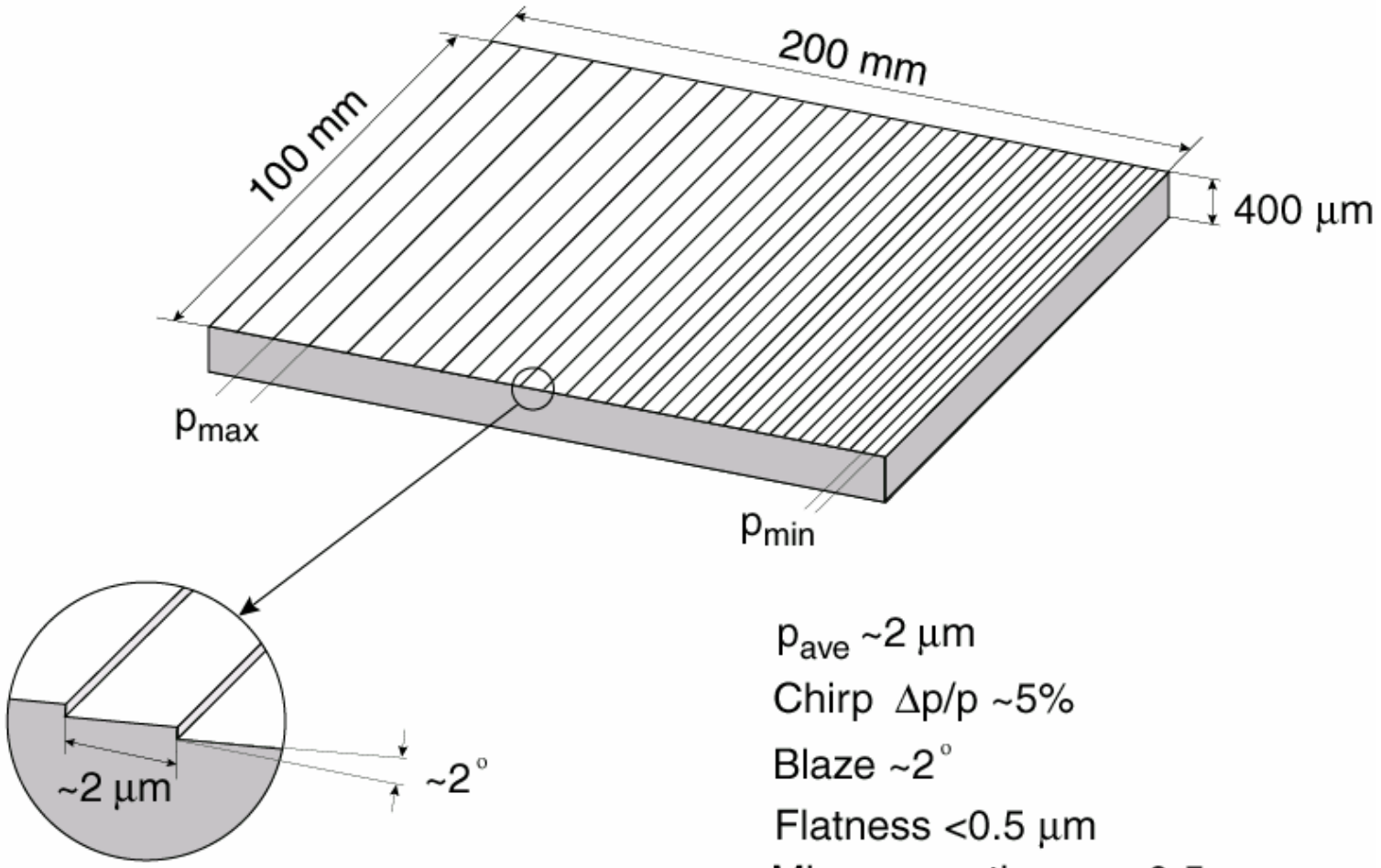
X-ray Reflection Grating Geometry



p_{ave} ~2 µm

Chirp $\Delta p/p$ ~5%

Blaze ~2°

Flatness <0.5 µm

Micro-smoothness <0.5 nm

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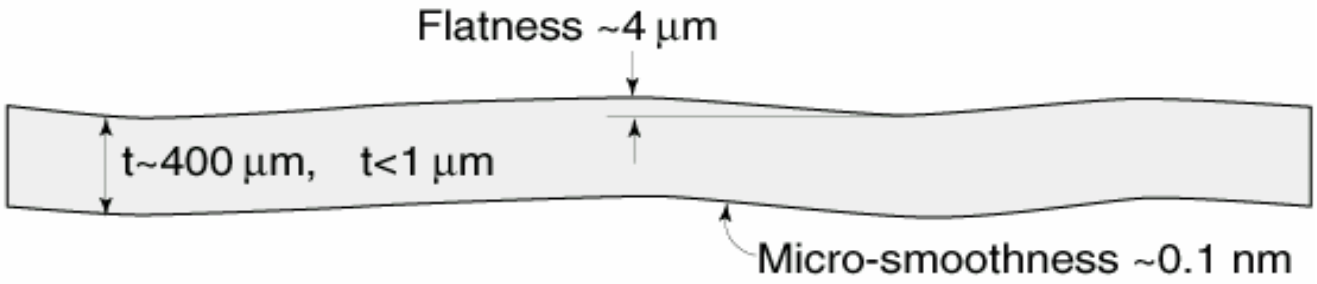
Flat Substrates

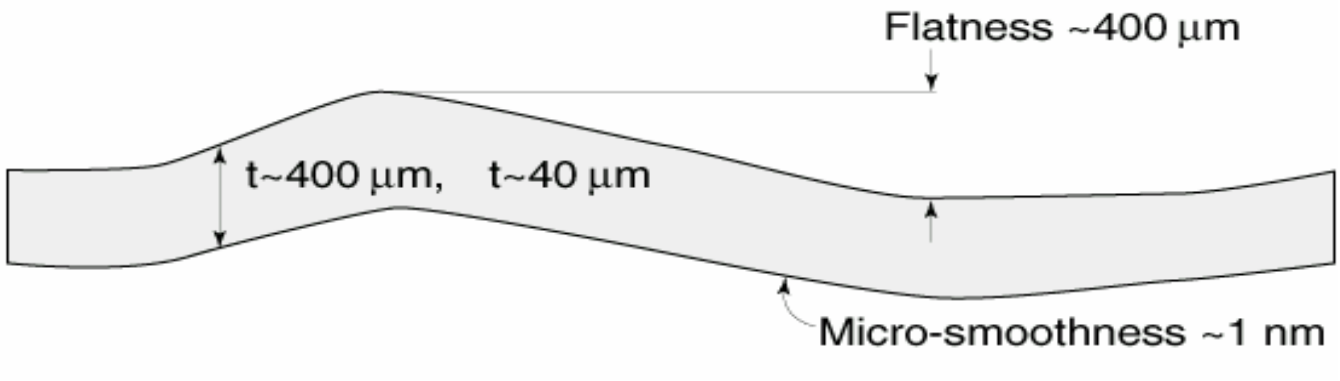
- Why
  - Image distortion
- Requirements
  - Silicon, Glass
  - 200-400 µm thick
  - 0.5-1.0 µm flatness
  - Avg. Surface Roughness $R_a < 1$ nm
- Techniques
  - Thermal Shaping, Block Lapping, MRF

Properties of Grating Substrates

Silicon Wafers



Glass Microsheets



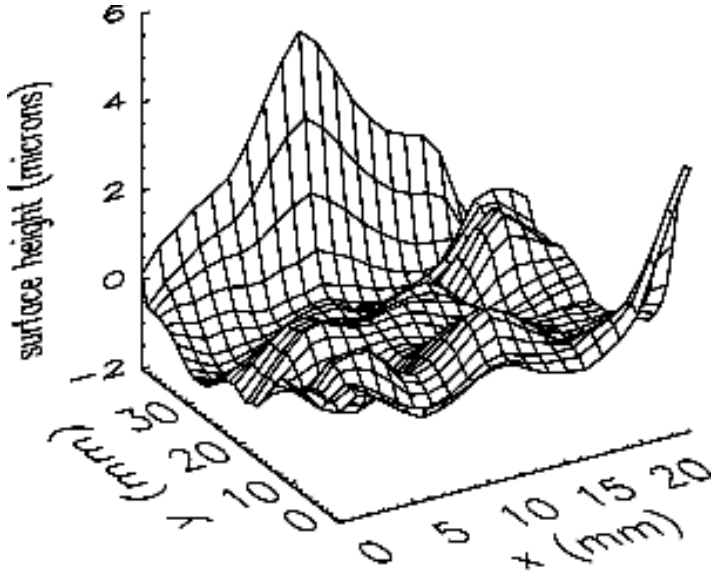
Thermal slumping of glass sheets

Heat the glass sheet to conform to flat surface

- Annealing temperature
- Optical flat plate

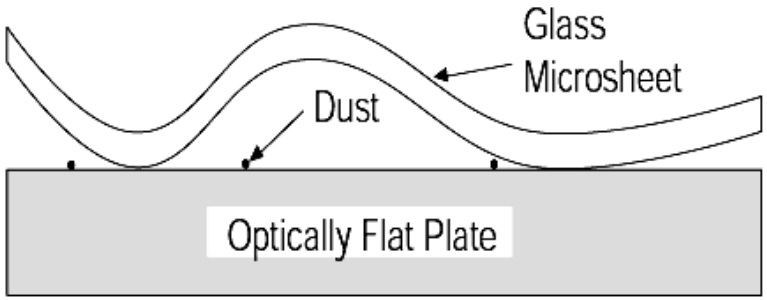
Results

- Flatness of 8 μm
- Bumps with 1-5 μm height

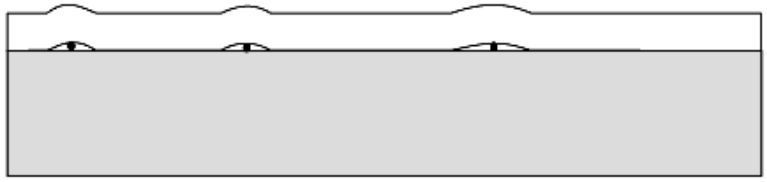


Thermal Slumping

Flat substrate with dust

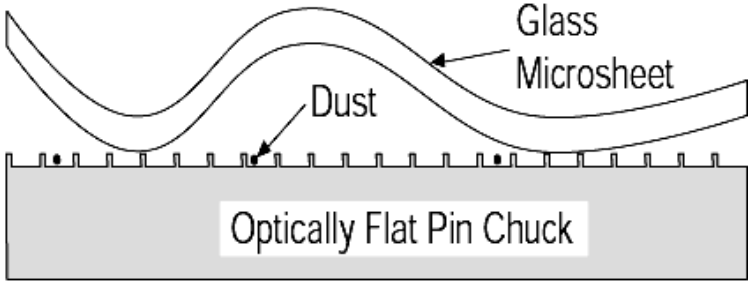


a) Before slumping.

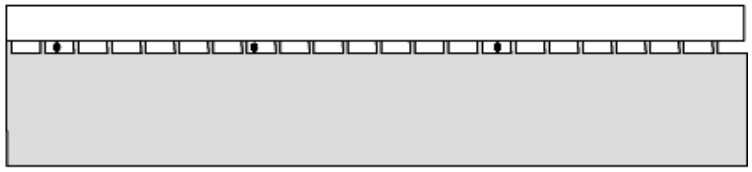


b) After slumping to flat plate.

Flat substrate with pin chucks



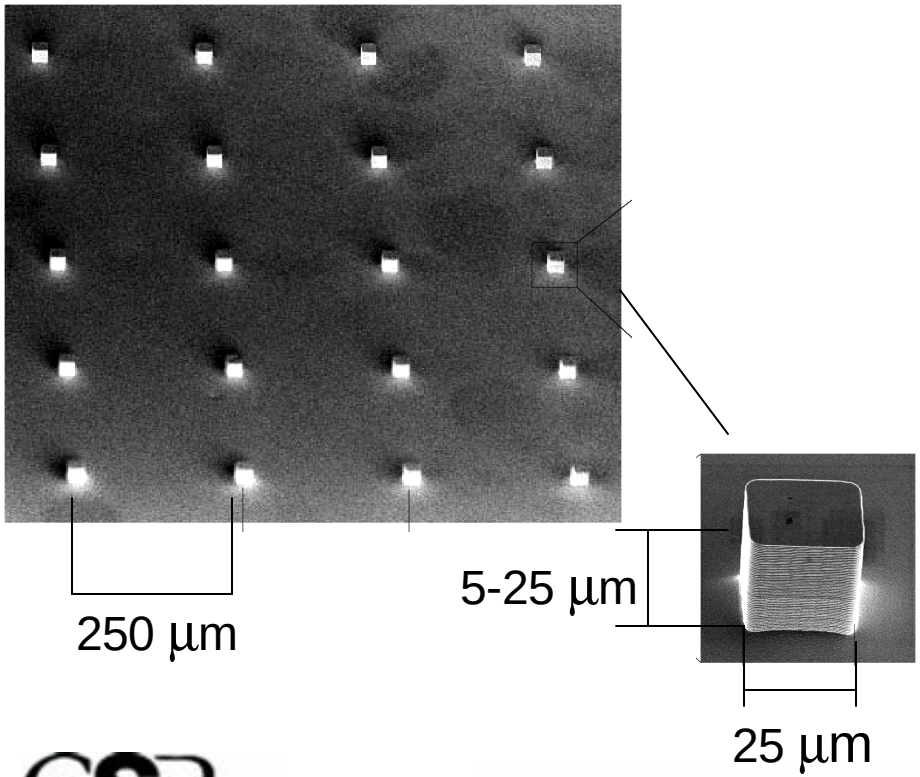
a) Before slumping.

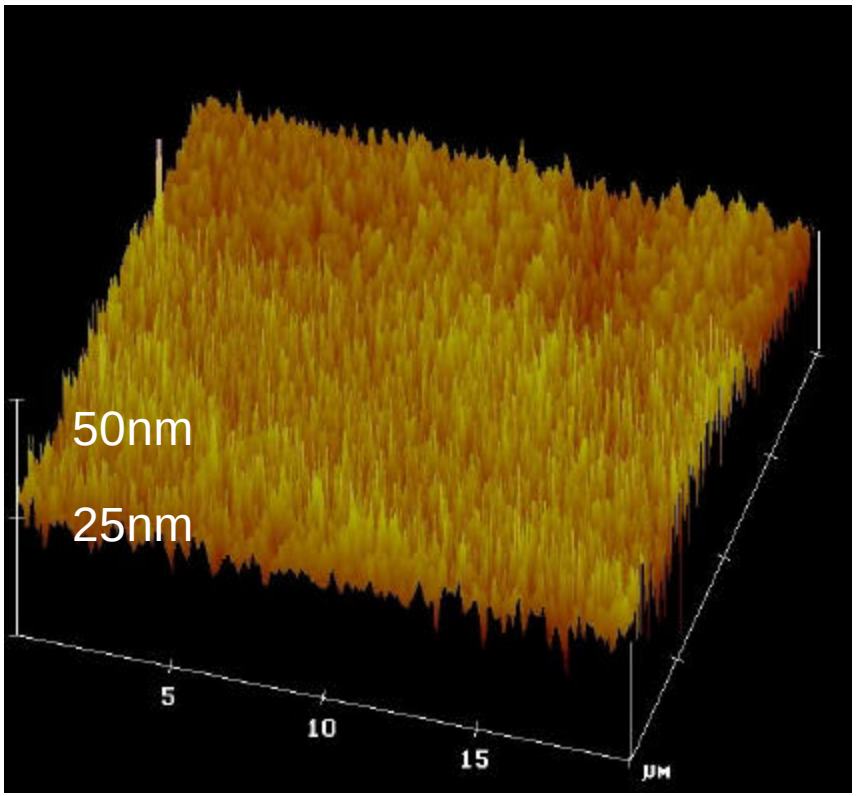


b) After slumping to flat pin chuck.

Artificial ‘dust’: Pin Chuck

- Microetched fused silica/silicon to get regular pin pattern
- TiO_2 coating to roughen the contact surface





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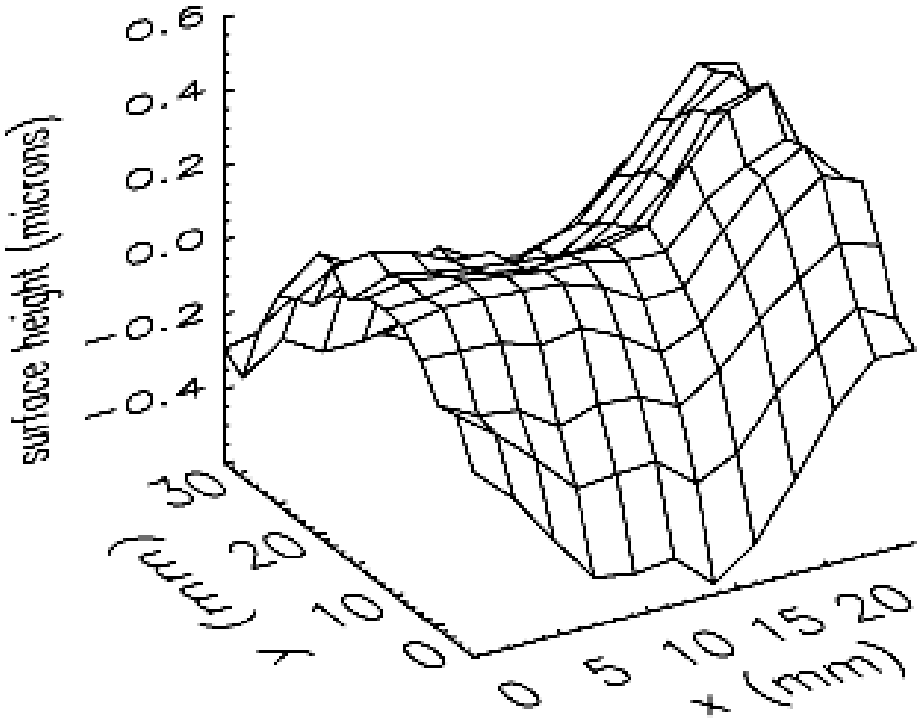
Slumping to pin chuck result



1 μm Flatness

Future Work

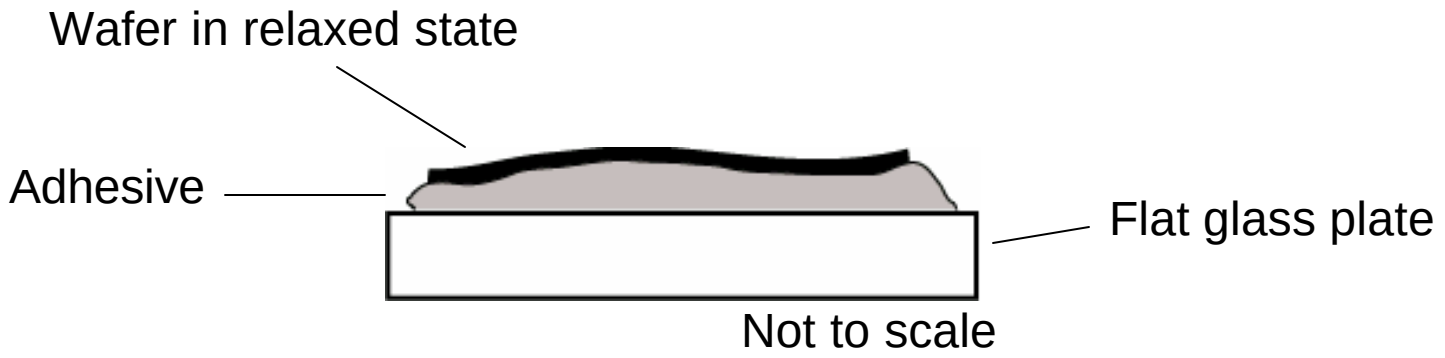
Larger sheets

Taller pins

New roughening method

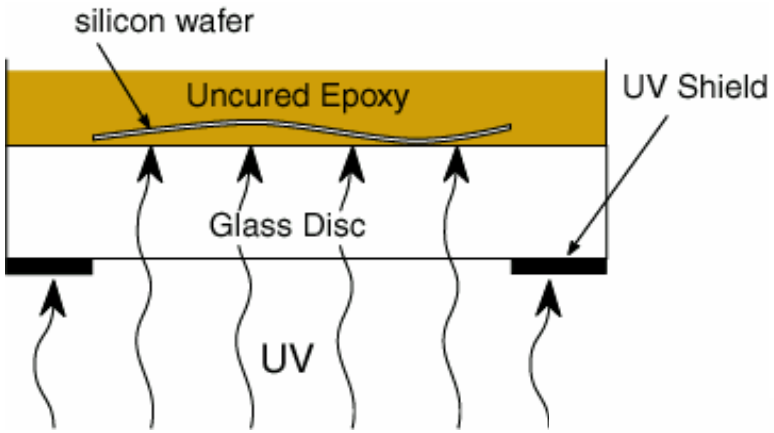
Block Lapping

- Concept
  - Bond Si wafer or glass microsheet to thick flat
    - D = 100 mm, t = 450 µm, flatness = 4 µm

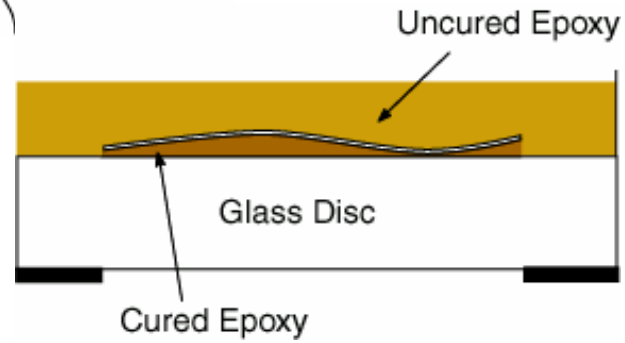


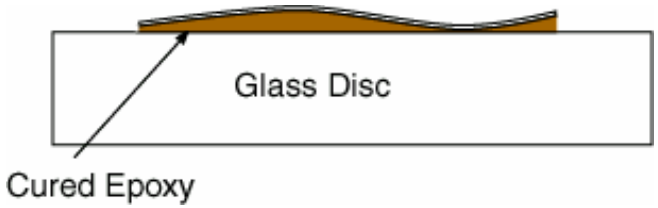
  - Polish wafer to 0.5 µm flatness
  - Release wafer

UV-cure Epoxy



Process





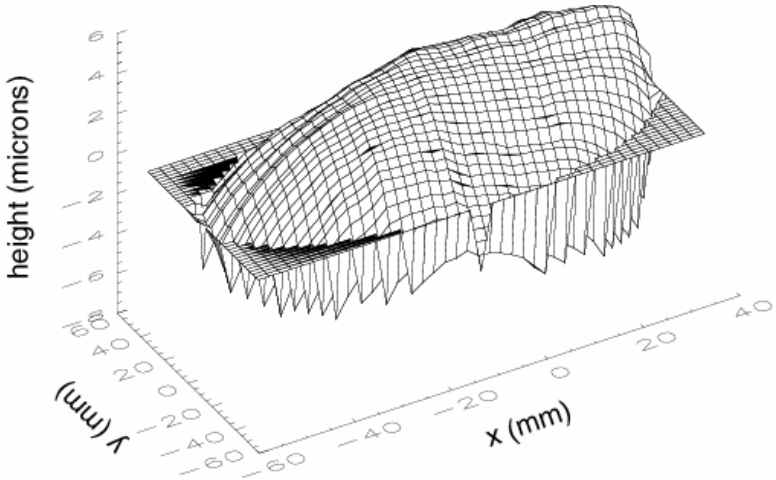
UV-cure Epoxy

Results

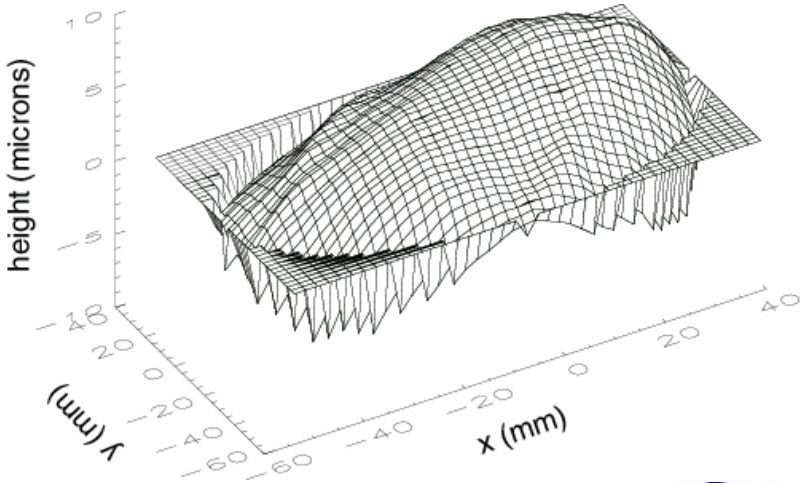
- Minimal distortion (0.5 μm)
- Measurement tool limit reached

- Unable to dissolve epoxy, release wafer

Before

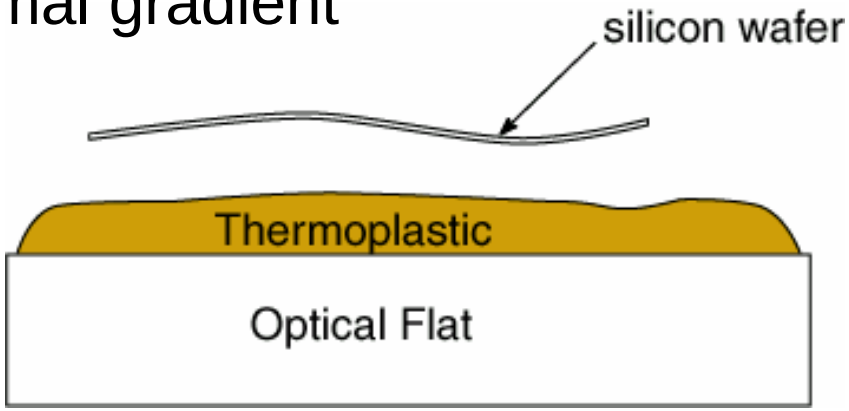


After



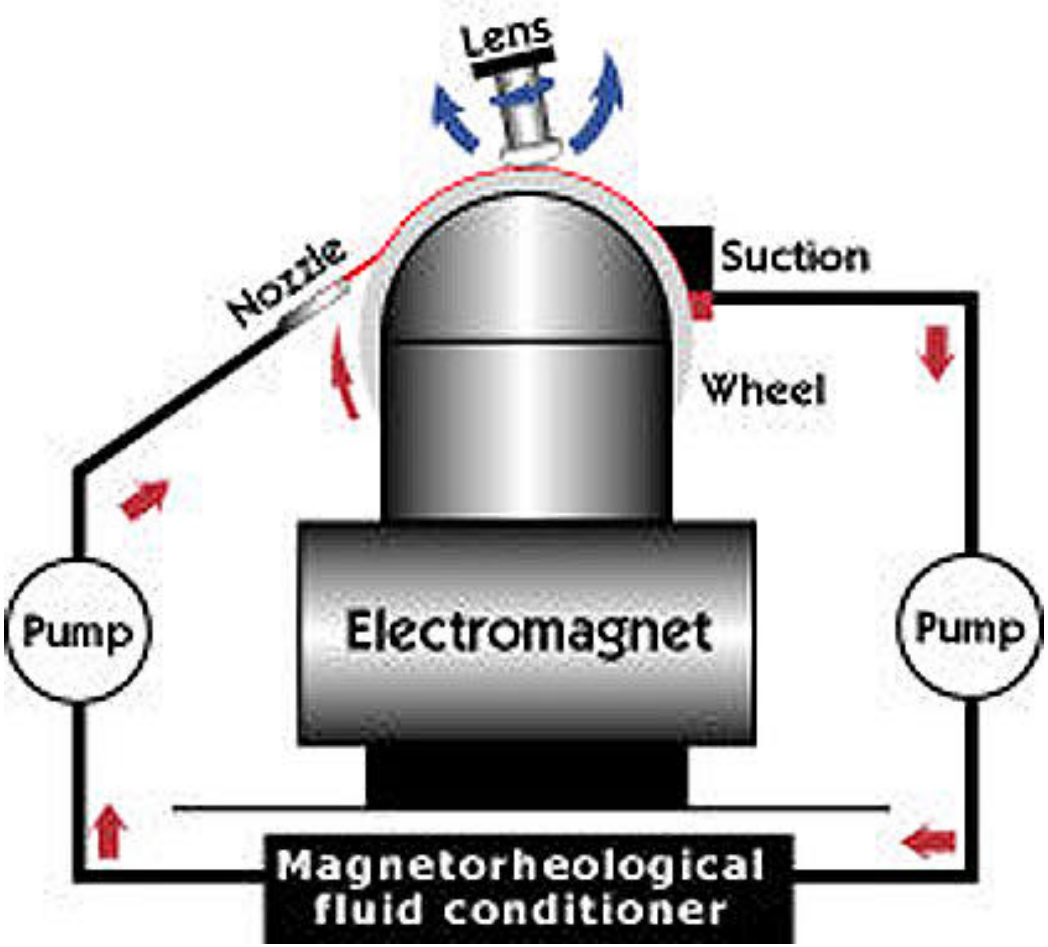
Thermoplastic Adhesive

- Process
  - Wafer placed on molten adhesive
  - Slow cool with no thermal gradient



- Results
  - Distortion comparable to epoxy experiment
  - Simple release procedure

Wafer polishing process with MRF



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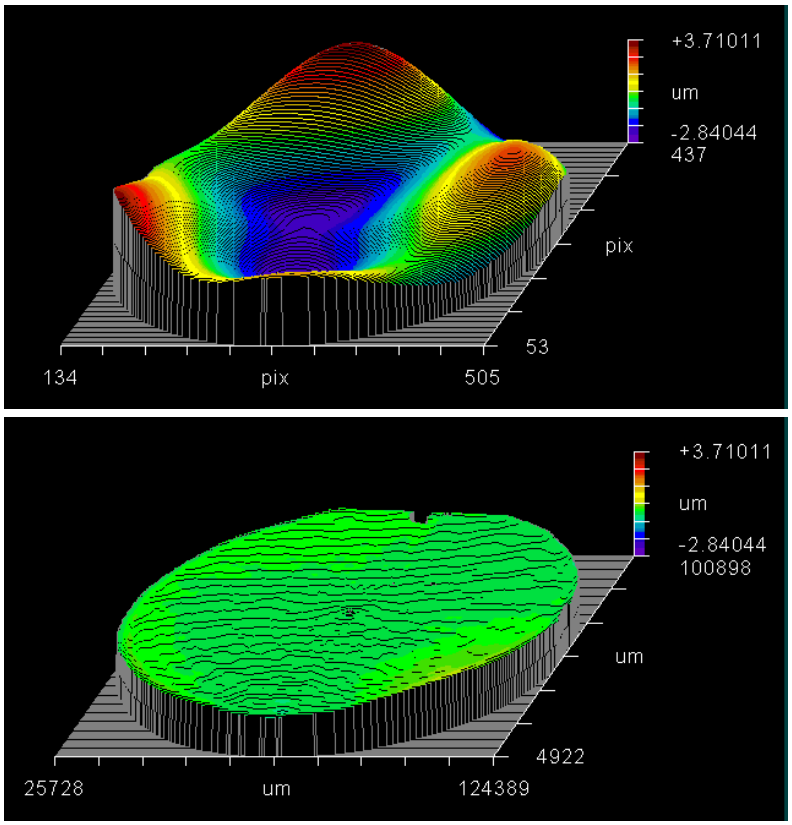
Wafer polishing results with MRF

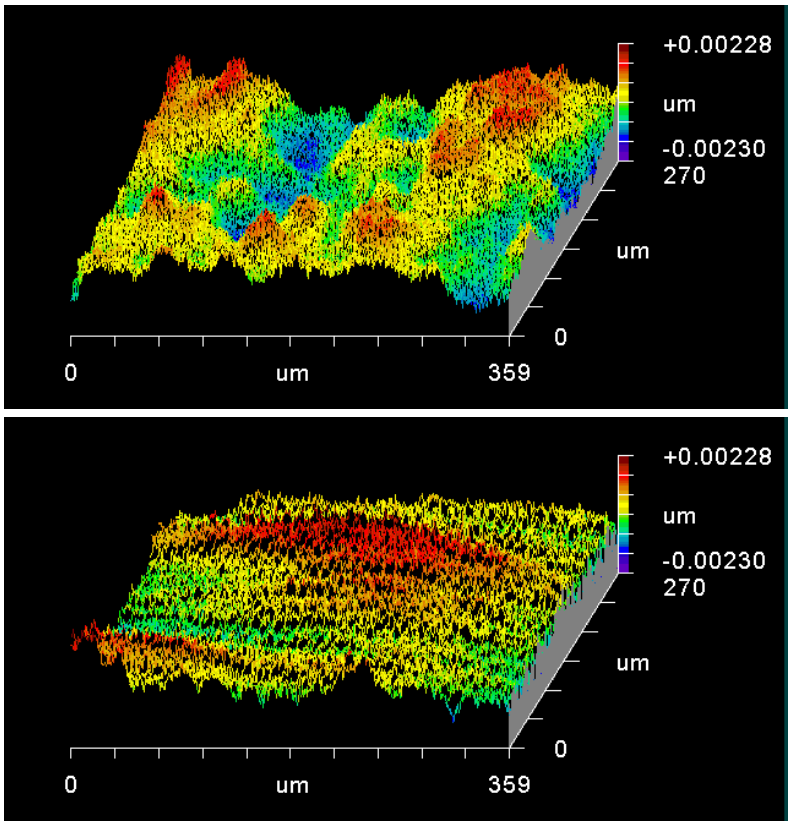
QED Technologies

Bow & Warp



Before - 6.55 µm ***After*** - 0.81 µm

rms microroughness



Before – 0.66 nm ***After*** – 0.64 nm

Material:	Silicon
Diameter:	100 mm
Thickness:	0.45 mm

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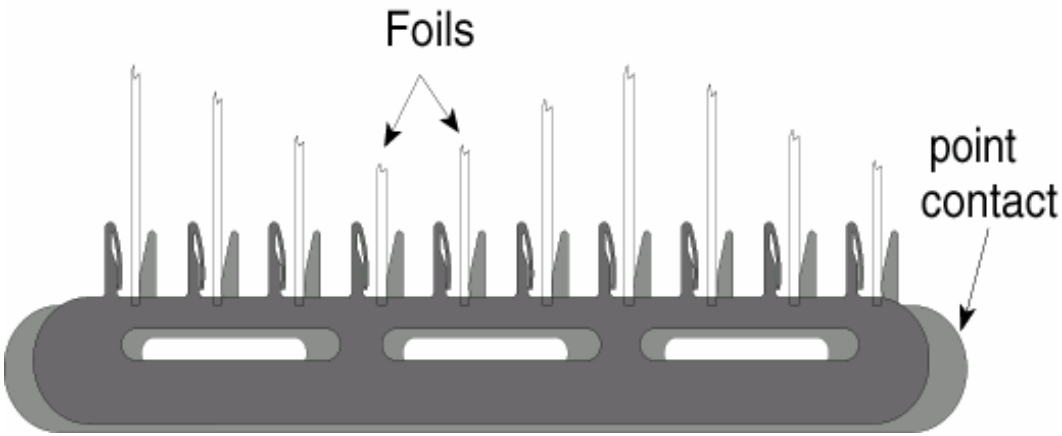
MIT 2nd Gen. Assembly Truss

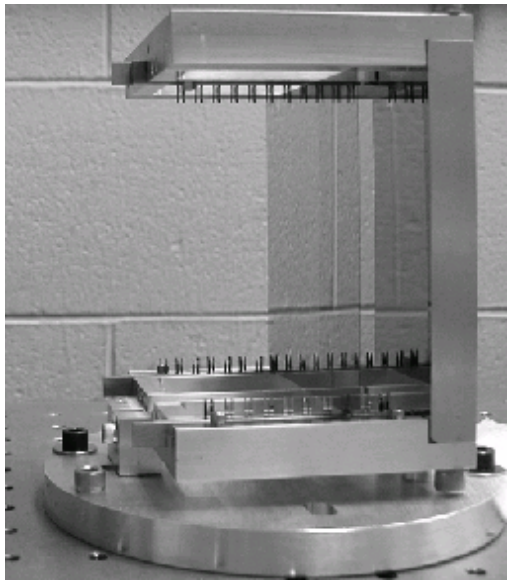
- Functional Requirements
  - Align gratings ¦ to within 1 μm of ideal
  - Repeatable use
  - Gratings fixed into place
    - Lightweight flight module ($$$)
    - Permit X-ray entrance/exit
    - Endure launch (mechanical, acoustic vibrations)
    - Endure space (thermal cycling)

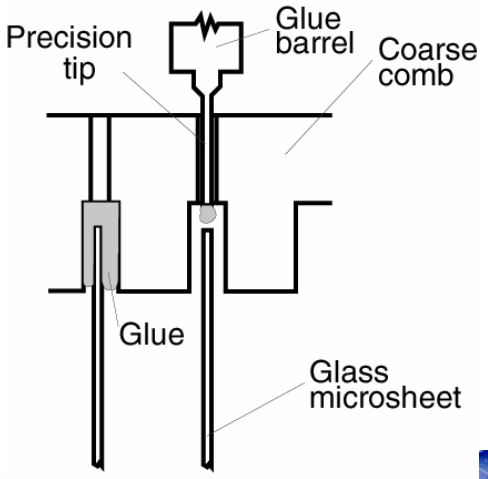
Strategy

Foils loosely aligned in flight module

Align foils using microcombs and reference surface





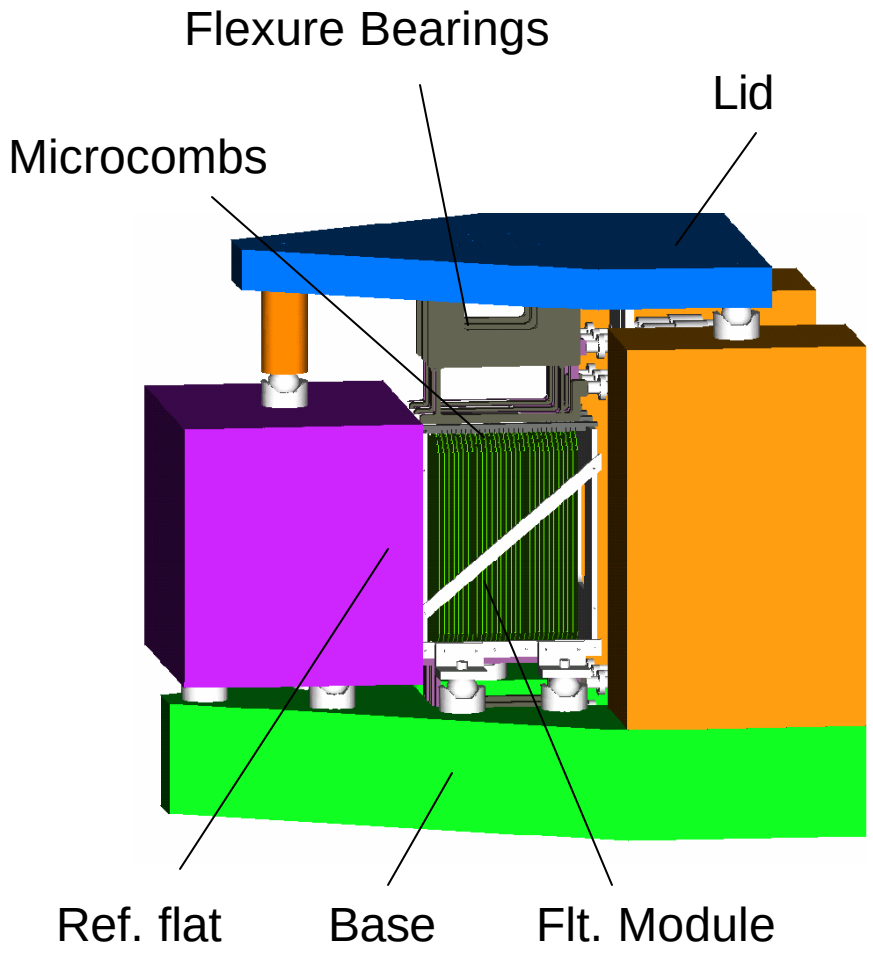


Glue foils into “coarse” combs in flight module

Concept

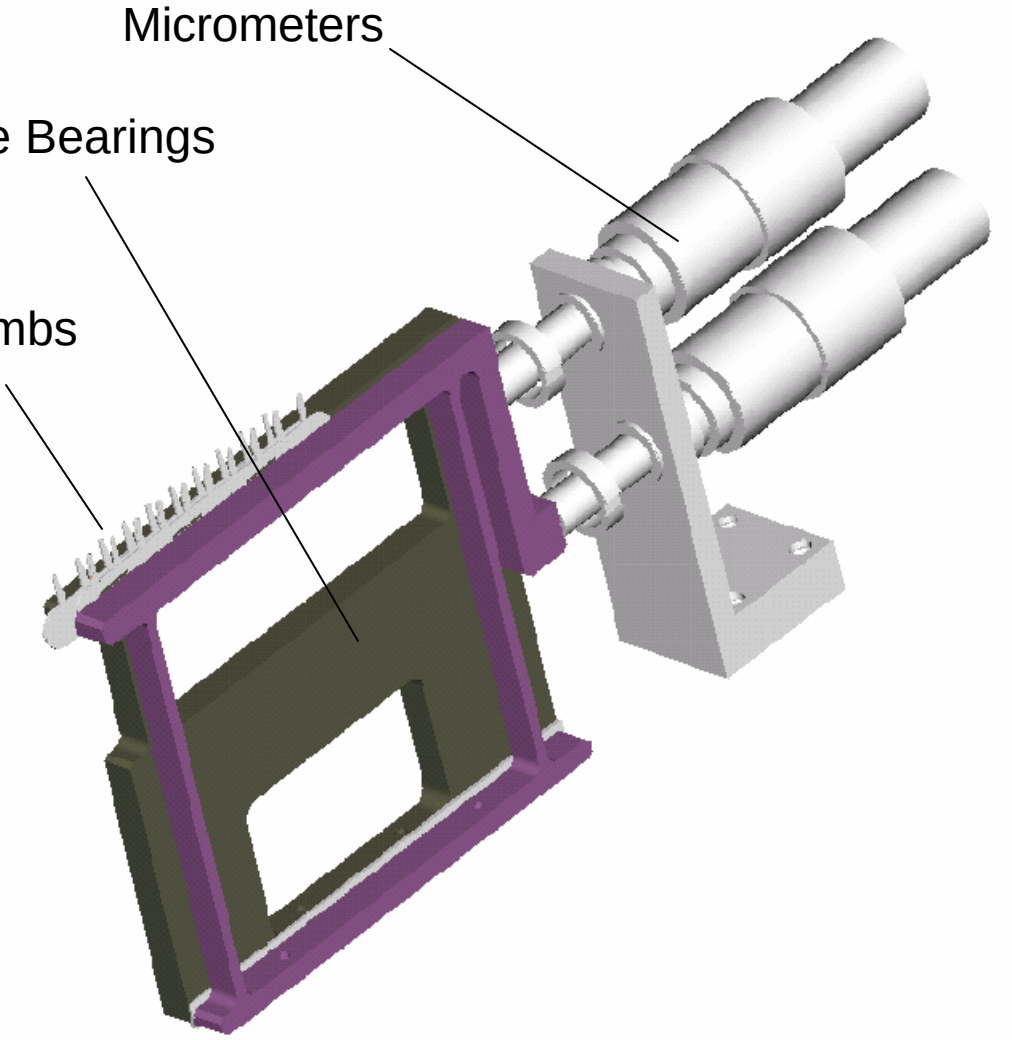
Assembly Process

- Put flight module in
- Put lid on
- Align reference combs
- Position gratings with spring combs
- Glue



Comb Alignment-Flexure Bearings

- Simple
- No friction
  - Sensitive
  - Long life
- Integrated force sensor
  - Ref. flat contact
  - Study comb damage



Microcomb Alignment

Micrometer Array

- ~1 mm actuation
- 0.1 µm resolution
  - Repeatable